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ORIGINAL ARTICLE

Correlation of the radiological predictive factors of inferior alveolar nerve injury with cone beam computed tomography findings

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Abstract

Aim: This study assessed the radiological signs considered predictive of inferior alveolar nerve (IAN) injury and correlated them with findings from cone beam computed tomography (CBCT).

Material and methods: This was a prospective study of patients who underwent CBCT scanning of mandibular third molars when panoramic radiographs indicated an 'increased risk' of IAN injury during extraction.

Results: Seventy-eight per cent of the teeth identified showed darkening across the root. Thinning or perforation of the cortical plate was found on CBCT. The group that exhibited loss of radiopaque lines across the root (68%), all of the scans showed contact between the nerve and root, with loss of cortication of the canal. Thirty per cent of the cases exhibited diversion of the canal. There was contact with the tooth in all cases, with the nerve either coursing through the roots (33%) or being 'sandwiched' between the root and the cortex to such an extent that the distortion resulted in part of the nerve being displaced beyond the apex of the tooth, creating an apparent change in direction.

Conclusion: Loss of radiopaque line and diversion of the canal were both associated with loss of cortication of the canal on CBCT, indicating that there was contact between the root and the contents of the canal. These two signs are crucial predictive signs of increased risk of IAN injury during third molar extraction. Darkening of the root displayed root and nerve contact in 76.9% of the cases studied and therefore very likely to indicate risk.

Introduction

The removal of third molars is one of the procedures most commonly performed by oral surgeons. Dysfunction of the inferior alveolar nerve (IAN) after mandibular third molar extraction, although uncommon, is probably one of the most undesirable consequences of this, and is acknowledge to be very distressing for the majority of patients[1]. Altered function of the IAN may be perceived by the patient as a 'tingling', 'numbness' or as a burning or painful sensation affecting the ipsilateral lower lip, chin, gingivae and teeth. The frequency of occurrence of this complication is reported in the literature to vary widely, from 0% to as high as 17.4% (Table 1).

It is generally accepted that unless the root of a mandibular third molar appears to lie in close proximity to (in some cases overlaps) the inferior alveolar canal, there is little (if any) anatomical risk to the nerve, but surgical risk is also both operator- and technique-dependent. In order to determine the relationship between the nerve and the tooth, standard preoperative evaluation relies on panoramic imaging. Several radiological predictors have been proposed to indicate a close relationship of the tooth root and the canal[8].

Table 1 Incidence of reported altered labial sensation following third molar removal

	Temporary alteration sensation (%)	Permanent alteration sensation (%)	Unspecified time of altered sensation (%)
Bell[2]	0	0	
Gülicher & Gerlach[3]	3.6	0.91	
Hill *et al.*[4]	<5	0	
Howe & Poyton[5]			5.17
Renton *et al.*[6]*	17.4	1.3	
Rood[7]	6.3	1.3	
Rood & Shehab[8]			2.6
Rud[9]			0.4–2.4
Valmaseda-Castellón *et al.*[10]	1.3	0.36	

*This study examined the outcome of only those patients whose third molars were considered to be at increased risk of IAN injury.

The three radiological signs previously reported to be most predictive of sensory disturbance following mandibular third molar removal are[5,8,11–13]

- Darkening of the root, which has previously been explained by a reduction of bulk of root substance due to the inferior alveolar canal or nerve grooving the root[5,8,9,11]
- Interruption of the 'radiopaque line' of the canal (white line), which has been attributed to the deep grooving or perforation of the root[5,11], or a loss of the cortical margin of the canal so the root is in contact with the nerve[14,15]
- Diversion of the canal which has been interpreted as indicating that the canal had perforated the root and 'been dragged' upwards during subsequent tooth eruption[11], or the root during development has displaced the nerve so that a change in direction appears[9,16].

With the development of limited cone beam computed tomography (CBCT), the increasing availability of such scanners in the dental environment and benefit to patients in terms of reduced radiation dose offered by this type of imaging over conventional CT scanning, the value of CBCT to aid the evaluation of the anatomical relationship of the IAN and the position of third molars is beginning to be realised. These scans allow the surgeon to gain an appreciation in all dimensions of the precise relationship between the inferior alveolar canal and mandibular third molar. This enhanced understanding of anatomical relationships may necessitate an alteration of the surgical approach to the removal of the tooth or allow the surgeon to plan an alternative risk reducing surgical technique, for example coronectomy. Little work has been done to correlate the signs predictive of IAN injury seen on panoramic or periapical radiographs with findings on CBCT. Only darkening of the root[17,18] and interruption of the radiopaque line[14,19] have been reported previously.

This investigation was undertaken to re-evaluate the interpretation of the radiological 'signs' generally accepted to indicate heightened risk of disturbing the function or integrity of the nerve following mandibular third molar removal by comparing panoramic images with CBCT reconstructions.

Method

Patients referred for the removal of impacted mandibular third molars were routinely assessed on a number of clinics using conventional panoramic radiographs. Clinicians (of various grades) were requested to identify patients considered to be at 'increased risk' of IAN damage using the accepted criteria suggesting a 'close relationship' between the tooth and the canal[8].

Only cases where the canal wholly or partially overlapped the roots and demonstrated one of the three most significant predictive signs: darkening of the root, interruption of the radiopaque line and diversion of the inferior alveolar canal, were included in this study. In addition, inclusion necessitated that the inferior alveolar canal was clearly identifiable mesial and distal to the lower third molar on panoramic radiographs.

The records of patients identified according to these criteria were then assessed independently by two of three experienced surgeons (CB, GU, OO). Radiographs were examined in a suitably darkened environment with a good quality light box, a viewing cone and magnification, to confirm the presence of at least one of the significant predictor signs. Only when both examiners agreed was the case considered to be 'high risk'.

When these 'high risk' cases were considered for surgical intervention, a CBCT scan (3DX Accuitomo Morita Co. Ltd, Tokyo, Japan) was arranged. The patient received the minimum exposure by using a collimated 40 mm × 40 mm × 40 mm window. These

CBCT images were examined independently by two oral surgeons (JPR and GU) in a suitably darkened environment, using a high-quality screen. Regular breaks were taken to avoid examiner fatigue. In the majority of cases, the course of the nerve was followed distally from where the inferior alveolar foramen became evident to the mandibular third molar, so that there was no ambiguity on the scan as to which radiolucency represented the IAN.

The images were viewed in all dimensions in order to identify the relationship between the nerve canal, roots and surrounding bone. Only cases in which both examiners agreed with the assessment were the results included in the study. Where more than one predictor sign was present on the radiograph, each sign was examined independently.

Results

A total of 50 impacted third molars exhibiting a degree of image overlap plus at least one sign of high risk on plain radiograph were examined in 47 patients. The patient group consisted of 32 females (68%) and 15 males (age range 21–63 years, mean 33.66 years), with 54% of the third molars being on the left side. In the majority of cases, more than one sign of risk was visible on the radiographs (50 teeth displayed 88 signs Table 2).

Table 2 Distribution of signs present on 50 teeth examined

Radiological sign	Number of cases
Darkening of root	39 (44%)
Interruption of radiopaque line	34 (39%)
Diversion of inferior alveolar canal	15 (17%)
Total	88 (100%)

Darkening of the root (Fig. 1)

This has previously been reported to be due to loss of tooth structure indicating ‘grooving’ by the canal or due to the loss of the cortical lining of the canal.

This sign was evident in 39 of the 50 third molars (25 females, 14 males).

CBCT findings

In only one of these cases was loss of tooth substance (grooving) identified (2.6%).

In all cases, however, there was loss of integrity of the cortical plate structure (Table 3) within the lingual (30 cases), buccal (three cases) or both (six cases) of the cortical plate. This was due to either the nerve canal (14 cases) or tooth substance (17 cases Fig. 2) being within the cortex (Table 4). In eight cases, ‘grooving’ of the cortical plate was due to both tooth and nerve canal.

Table 3 Cortical plate exhibiting thinning where darkening featured as a predictive sign

Cortical plate with thinning	Number	Percentage
Lingual	30	76.9
Buccal	3	7.7
Both	6	15.4
Total	39	100.0

Table 4 Cause of cortical bone loss

Cortical plate with bone loss	Due to nerve *n* (%)	Due to tooth *n* (%)	Due to both *n* (%)	Total
Lingual	13 (33.3)	13 (33.3)	4 (10.3)	30
Buccal	1 (2.6)	2 (5.1)	0	3
Both	0	2 (5.1)	4 (10.3)	6
Total	14 (35.9)	17 (43.5)	8 (20.6)	39

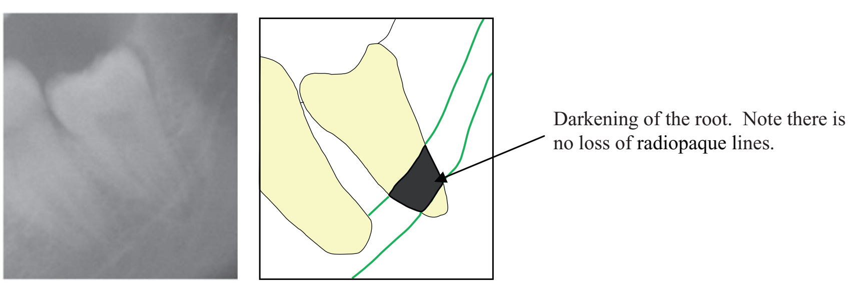

Figure 1 Darkening across the root of the lower left third molar shown on panoramic radiograph with schematic diagram (canal in green).

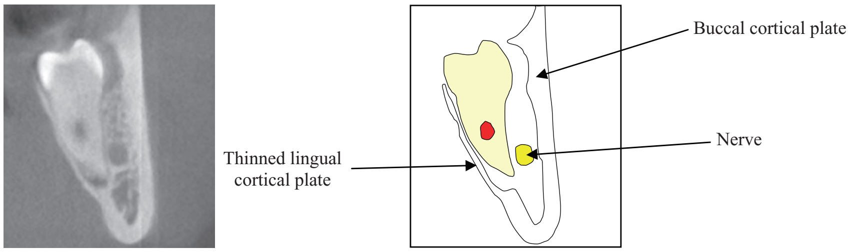

Figure 2 Coronal section of cone beam computed tomography (CBCT) of tooth in Figure 1 showing thinning of lingual bone. Note the buccal position of the nerve (dark yellow) with no contact with the root.

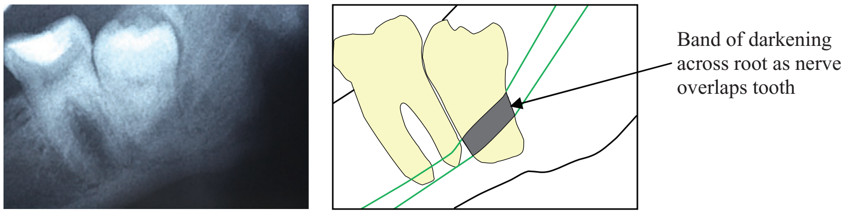

Figure 3 Panoramic image of lower left third molar exhibiting darkening across the root as the nerve overlaps.

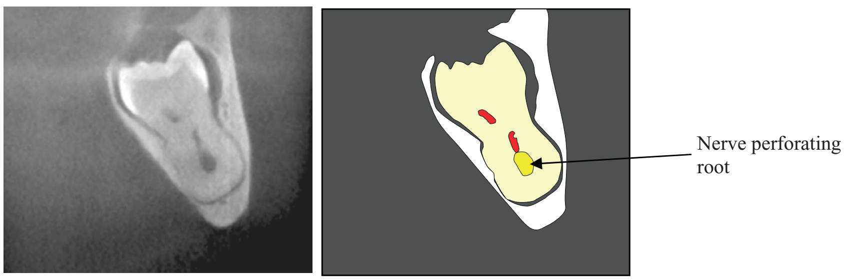

Figure 4 Coronal image of CBCT of mandibular left third molar from Figure 3 demonstrating loss of both lingual and buccal cortical plates with perforation of the root by the nerve.

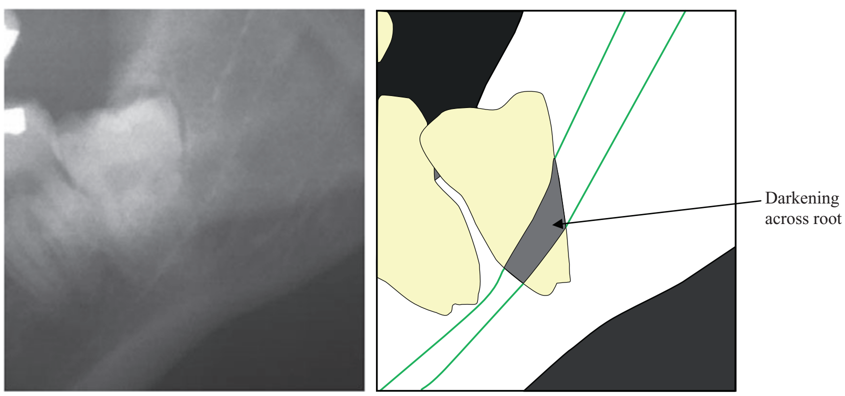

Figure 5 Panoramic radiograph illustrating darkening of the root.

Of the 22 cases where cortical plate loss was due in part to the position of the nerve (14 + 8), 20 cases involved loss of structure of the lingual cortical plate and two involved the buccal cortical plate.

In 25 cases (17 + 8), there was loss of cortical plate structure due to part of the tooth being situated within it (5 buccal, 18 lingual, 2 both). Where loss of both cortical plates was due to the position of the tooth, the nerve passed through the substance of the tooth that is perforated the root (Figs 3 and 4).

Of the 38 cases where grooving was not evident on the CBCT, the nerve was in contact with the tooth in 29 cases, that is the other nine cases displayed no contact between tooth and nerve (Figs 5 and 6).

In one case (Figs 7 and 8), a substantial portion of the tooth was found to be present within the thinned lingual plate, but the localised darkening on the plain film

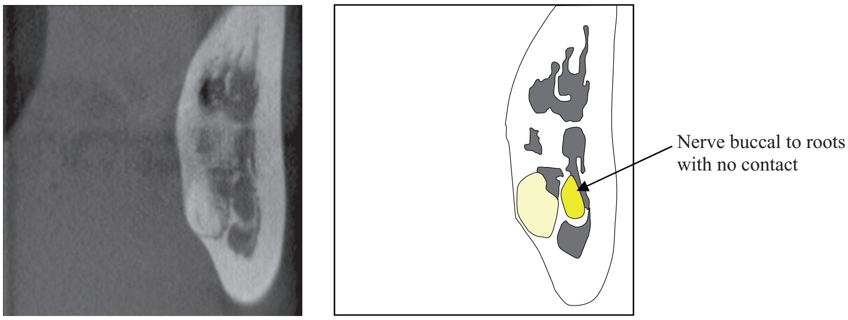

Figure 6 Coronal CBCT of Figure 5 illustrating the buccal position of the nerve with no contact with the roots.

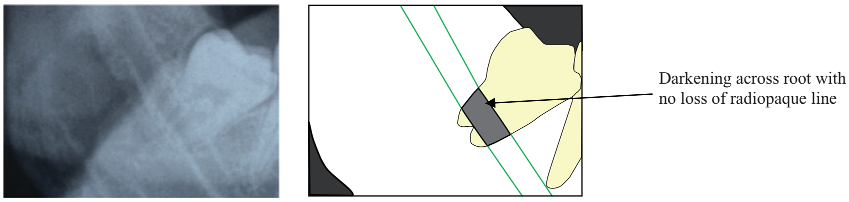

Figure 7 Panoramic image of lower right third molar exhibiting darkening of the root as the inferior alveolar nerve (IAN) overlaps.

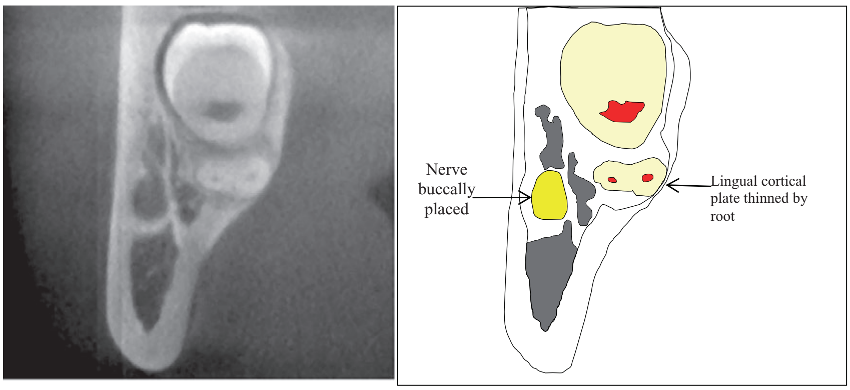

Figure 8 Coronal CBCT of Figure 7 demonstrating loss of lingual cortical plate by tooth substance only. Note buccal position of nerve.

appeared to coincide with the superimposed image of the (soft tissue) canal which was separated from the tooth by cancellous bone (there was no loss of radiopaque lines).

Interpretation

Darkening, evident on plain films does *not* indicate grooving of the tooth root but a reduction in the thickness of either the buccal or lingual cortex by the nerve, root or both. The linear image of darkening can also be explained by the superimposition of the nerve canal over the area of cortical bone loss (Figs 1, 2, 5 and 6).

Interruption of the radiopaque line (Fig. 9)

This has been considered to indicate close contact between the canal and tooth, resulting in loss of part of the cortical margin of the canal.

This sign appeared in 34 of the 50 cases (22 females, 12 males).

CBCT findings

Loss of cortication of the inferior alveolar canal was evident in all of the cases (Fig. 10), with the contents of the canal being in contact with the tooth in every case. Additionally, 21 (62%) demonstrated loss of the canal cortication attributed to contact of the canal with the lingual (17 cases) or buccal (four cases) cortical plates.

Interpretation

On plain films, loss of a radiopaque line *does* indicate 'contact' between the IAN canal and tooth structure.

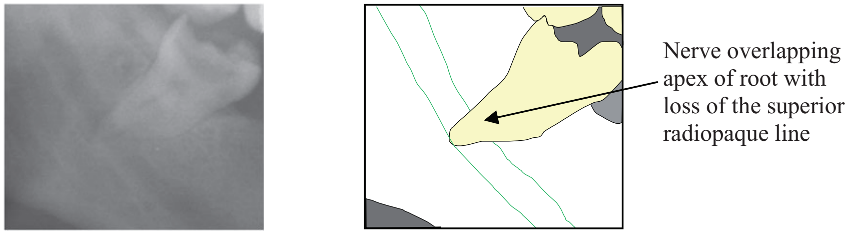

Figure 9 Panoramic view of carious lower right third molar exhibiting loss of radiopaque lines as the nerve crosses the root.

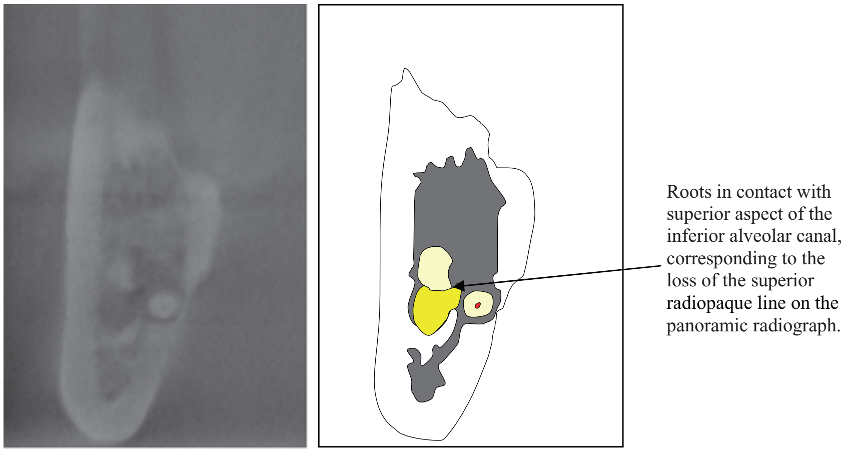

Figure 10 CBCT of Figure 9 illustrating the loss of cortication of the inferior alveolar canal as it passes the roots of the lower right third molar.

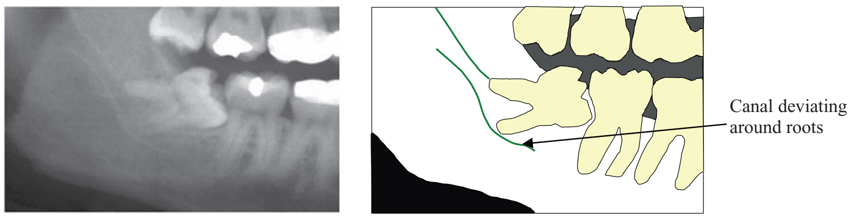

Figure 11 Panoramic radiograph showing diversion of the lower 'radiopaque' line around the mesial root of mandibular right third molar.

Diversion of the canal (Figs 11 and 13)

This has been taken to indicate close contact between the IAN and the mandibular third molar and has been explained by the developing root causing displacement of the course of the canal.

This sign was present in 15 of the 50 cases (10 females, 5 males).

CBCT findings

There was contact between the canal and root in all 15 cases. All 15 cases also demonstrated loss of cortication of the canal at the point of contact. In 10 cases, the nerve was 'sandwiched' between the cortical plate and root to such an extent that the nerve deviated around the root apex (Fig. 12).

Where the nerve was not positioned between tooth and the cortical plate (five cases), the diversion was a result of the nerve weaving itself between the roots (Figs 13 and14).

Interpretation

Diversion of the canal seen on plain radiograph correlates with either the nerve coursing between the roots of the lower third molar, or the nerve being 'sandwiched' between the root and cortical bone to such an extent distortion of the nerve results in an alteration of direction.

Discussion

Panoramic radiography is invaluable in illustrating the proximity of the IAN and mandibular third molar.

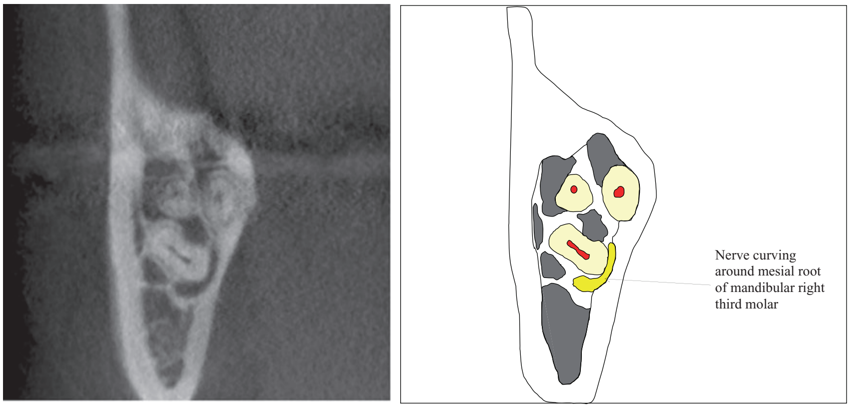

Figure 12 Coronal CBCT scan of tooth in Figure 11, with schematic diagram illustrating the displacement of the nerve contents to curve around the mesial root.

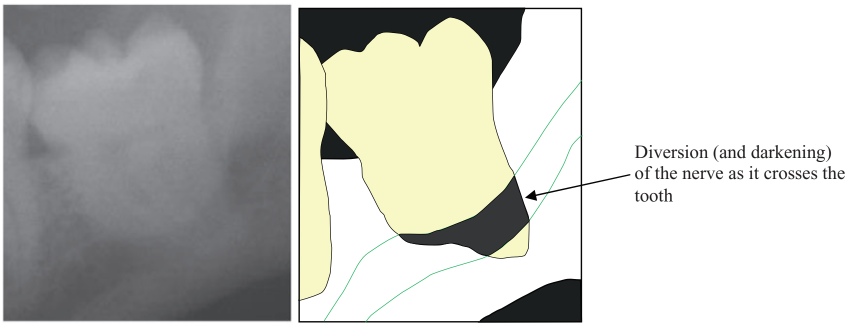

Figure 13 Panoramic radiograph of the lower left third molar illustrating diversion of the inferior alveolar canal (green) as it overlaps the tooth.

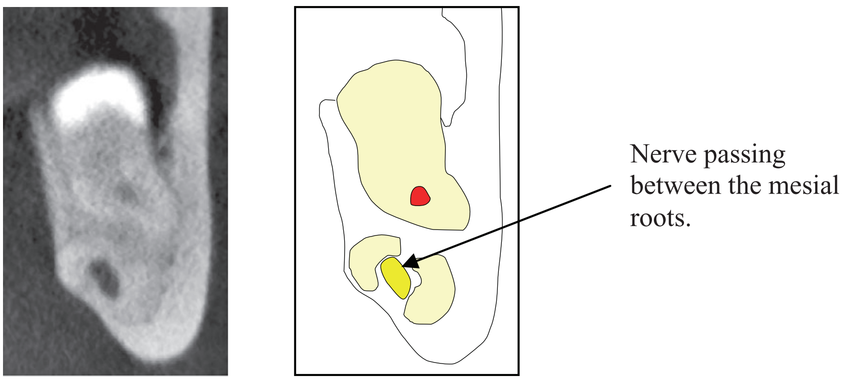

Figure 14 Coronal slice of the CBCT of Figure 13 illustrating the nerve passing through the roots as the nerve passes the roots.

CBCT is proving to be increasingly beneficial in determining the precise relationship between these two structures in those individuals where the panoramic radiograph suggests the relationship to be close[20]. The CBCT images can be reformatted with minimal distortion allowing the canal and tooth to be viewed in all dimensions[21]. Its use results in patients receiving a greater radiation dose compared to standard radiography; therefore, it is not appropriate for CBCT to be used as the first routine imaging technique, and should be applied when the benefits of the additional exposure are likely to be considerable.

The present study reveals some misconception in the interpretation of the radiological predictors traditionally believed to be indicative of increased risk of IAN damage.

The study was designed to examine the three findings said to be significantly related to IAN injury[8]: darkening of the root, interruption of the radiopaque line and diversion of the inferior alveolar canal.

Numerous studies have previously attributed darkening across the root to reflect grooving of the root and hence loss of tooth substance[5,8,11,22]. Grooving is indicated by the existence of a concavity or invagination in which the canal will lie. Curvature of the root apex around the canal may be illustrated by a hook or notch[22]. This concept was recently evaluated using with CBCT[17,18], and it was proposed that the darkening is not due to the loss of calcified substance in the tooth, but the loss of calcified substance of the buccal and/or lingual cortical plates. Our study supports this conclusion, and attributes the darkening not to loss of tooth substance, but in fact to thinning of a cortical plate. Only one case demonstrated grooving of the tooth (2.6%), but thinning of the cortical bone was also present. Also noted in our findings was that 36 cases demonstrated thinning of lingual cortex and in some cases this was so pronounced that there was perforation of the lingual plate. This finding is highly relevant to the oral surgeon as it may alter the technique of extraction, thereby lowering the risk for lingual nerve damage, fracture of the lingual cortex or herniation of root fragments into anatomical spaces such as lingual fossa or sublingual space. In addition, such risks can be discussed further with the patient thereby allowing the surgeon to obtain a more secure informed consent.

In some cases, loss of the cortical plates occurred adjacent to the crown of the tooth, in addition to the roots. It was noted however the panoramic radiograph of these cases did not exhibit darkening in the coronal area. This could be due to the superimposition of the radiopaque enamel of the crown masking any darkening which may be present, whereas in the apical portion, there is superimposition of the radiolucent canal over an area of bone loss. Moreover, the linear appearance of darkening across the roots can be explained by the superimposition of the nerve coinciding with the area of cortical bone loss.

In conclusion, the darkening of the root is not due to the grooving of the tooth as proposed in previous studies, but due to the grooving of the cortical plate.

Although darkening does not indicate grooving of the tooth, 30 of the 39 cases of third molars in this group were in contact with the IAN. Thus, manipulation of the tooth during extraction may exert some force on the nerve, which may result in some altered sensation, confirming that this sign is predictive of an increased risk of nerve injury.

The interruption of the 'radiopaque lines' has been attributed to contact of the roots with the nerve[5,8,11,14,19]. Our study corroborates this finding. One hundred per cent of cases exhibiting loss of the radiopaque line on panoramic radiographs also displayed loss of cortication of the canal on CBCT, with the roots in contact with the contents of the canal. Therefore, it seems highly probable that if these teeth were to be extracted, the nerve would be exposed and may be visible in the socket[19]. There is also a risk of IAN damage during extractions to this group of patients as manipulation of the root may inadvertently cause compression of the nerve. It was also noted that in four patients of this group (12%), the nerve either coursed between the buccal and lingual roots of the tooth or perforated the root. CBCT imaging will aid planning the surgical approach to extractions in these patients.

In conclusion, loss of a radiopaque line of the canal across the root does indicate contact with the nerve and its contents, as there is loss of the cortical structure of the canal and confirms potential injury to the nerve during extraction.

Diversion of the nerve is said to be attributed to the nerve being displaced during the development of the tooth[11,16]. In our study, diversion was found to be related to the distortion of the nerve as it passed by the root (10/15 cases), or passing between the roots (5/15 cases). All cases exhibited nerve and root contact. Manipulation of the tooth during extraction may result in compression of the nerve.

In their 2005 article, Renton *et al*.[6] described a 'new' radiological feature: the juxta-apical area and suggested that it was predictive of an increased risk of nerve injury. This 'new sign' was also noted the panoramic radiographs of some of the patients in our study (Fig. 15).

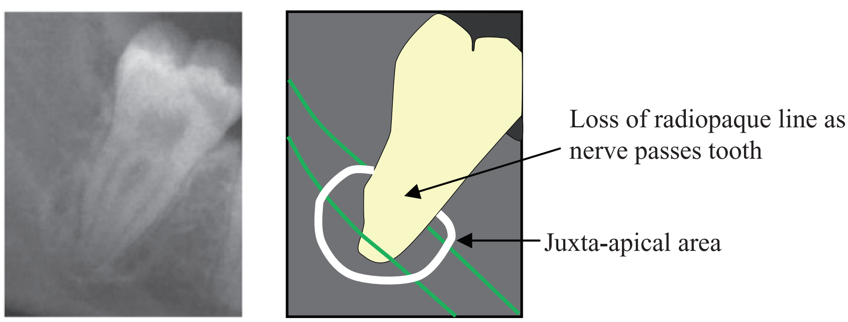

Figure 15 Panoramic radiograph illustrating the 'juxta-apical area' on the lower right third molar.

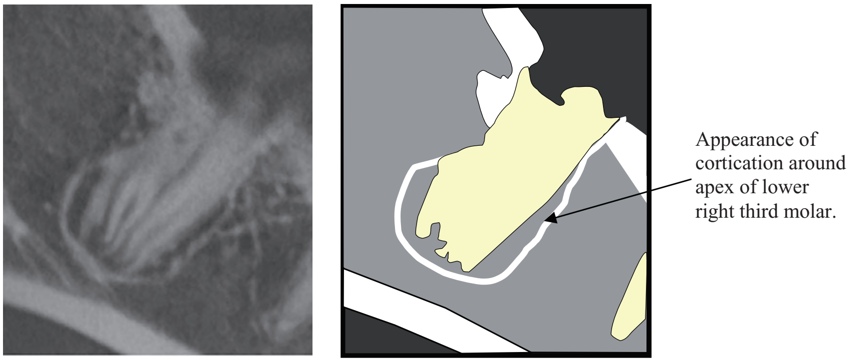

Figure 16 Sagittal CBCT slice of case illustrated in Figure 15 demonstrating the extent of the large cancellous bone space.

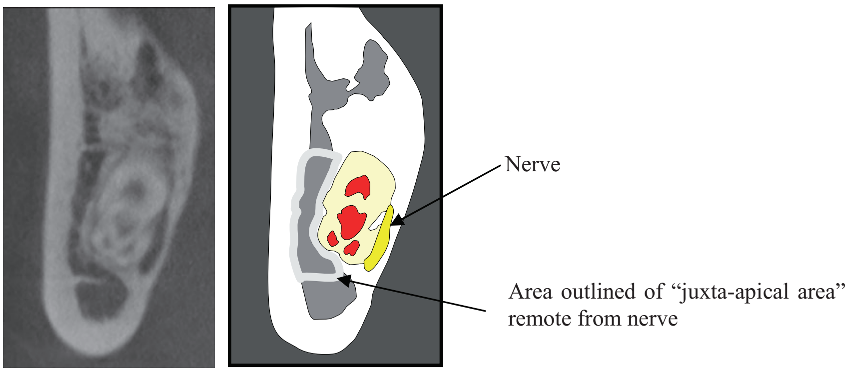

Figure 17 Coronal slice of Figure 15 illustrating lingual position of the nerve and the buccal position of the 'Juxta-apical area'.

When these areas were examined on the CBCT, the appearance related to a particularly large cancellous bone space. This phenomenon was noted on several scans (Figs 16 and 17). Thus our study suggests that the 'juxta-apical area' *per se* is not a sign of increased risk, but rather a superimposition of the canal over large cancellous bone spaces – an image created by cancellous bony architecture rather than pathology.

The results of our study suggest that for those patients where plain film indicates an increased risk of IAN injury during extractions of mandibular third molar, CBCT can clarify the position of the nerve in all dimensions and improve surgical planning to reduce the risk of this complication. It may also prove to be reassuring when no contact between the root and the nerve is observed on CBCT and therefore patients can be reassured that there is no increased risk of nerve injury.

Conclusion

CBCT has significantly improved our understanding of the relationship between mandibular third molars and the inferior alveolar canal previously described by panoramic radiography. We have demonstrated that darkening of the root correlates to thinning of lingual or buccal cortical plate (by either the tooth or the nerve.) Loss of radiopaque lines indicates that the canal and hence its contents are in contact with tooth. Diversion of the canal correlates to the course of the nerve being altered as it contacts and passes the roots due to space restriction in the mandible.

Of the predictive signs observed on panoramic radiographs, loss of cortication and/or diversion of the canal are highly suggestive of nerve/root contact.

All three signs reflect a risk relationship between tooth and nerve which is confirmed by CBCT. Planning the surgical removal of lower third molars can be effectively and precisely enhanced with the use of CBCT, which provides not only an accurate understanding of the position of the nerve in relation to the third molar, thereby facilitating a risk reducing surgical approach or treatment (Figs 18–20), but also other potential complication, for example, risk of herniation of tooth fragments into the lingual fossa when the lingual cortical plate, is thinned substantially.

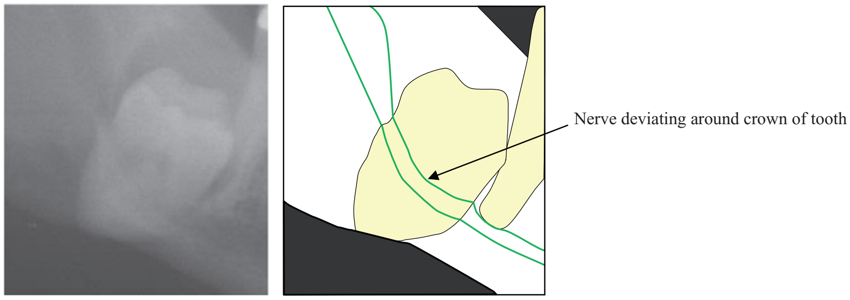

Figure 18 Panoramic radiograph of lower right third molar illustrating diversion of the nerve as it overlaps the root.

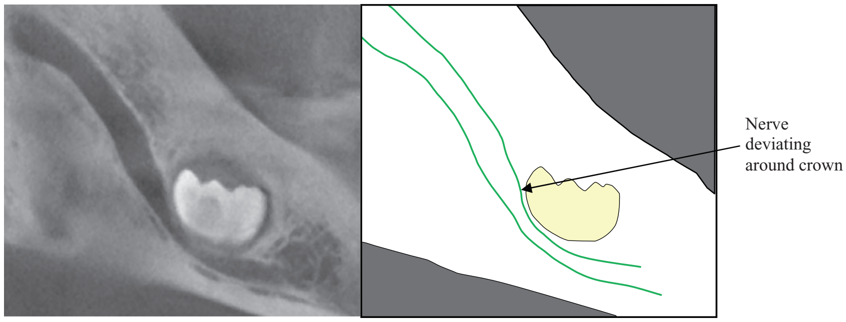

Figure 19 Sagittal slice of CBCT of the tooth in Figure 18, illustrating the diversion of the nerve related to the crown.

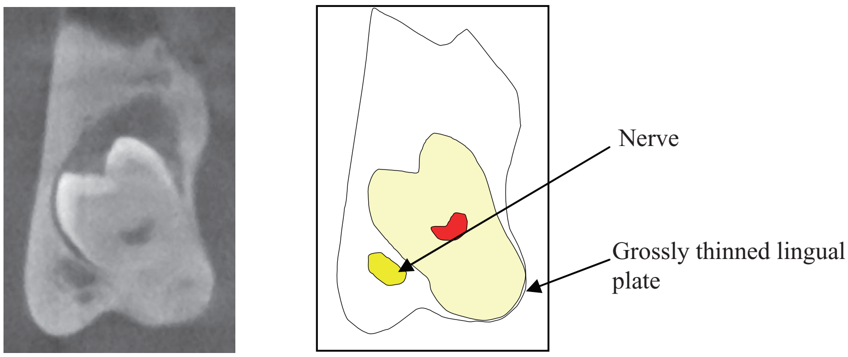

Figure 20 Coronal slice of CBCT of Figure 18, illustrating the buccal position of the nerve related to the crown and the lingual position of the roots with the thinned lingual plate, with potential risk of herniation into the lingual fossa during surgical extraction.

References

1. Ziccardi VB, Zuniga JR. Nerve injuries after third molar removal. Oral Maxillofac Surg Clin North Am 2007;19: 105–15.
2. Bell GW. Use of dental panoramic tomographs to predict the relation between mandibular third molar teeth and the inferior alveolar nerve. Radiological and surgical findings, and clinical outcome. Br J Oral Maxillofac Surg 2004;42:21–7.
3. Gülicher D, Gerlach KL. Sensory impairment of the lingual and inferior alveolar nerves following removal of impacted mandibular third molars. Int J Oral Maxillofac Surg 2001;30:306–12.
4. Hill CM, Mostafa P, Thomas DW, Newcombe RG, Walker RV. Nerve morbidity following wisdom tooth removal under local and general anaesthesia. Br J Oral Maxillofac Surg 2001;39:419–22.
5. Howe GL, Poyton HG. Prevention of damage to the inferior dental nerve during the extraction of mandibular third molars. Br Dent J 1960;109:355–63.
6. Renton T, Hankins M, Sproate C, McGurk M. A randomised controlled clinical trial to compare the incidence of injury to the inferior alveolar nerve as a result of coronectomy and removal of mandibular third molars. Br J Oral Maxillofac Surg 2005;43:7–12.
7. Rood JP. Permanent damage to inferior alveolar and lingual nerves during the removal of impacted mandibular third molars. Comparison of two methods of bone removal. Br Dent J 1992;172:108–10.
8. Rood JP, Nooraldeen Shehab BAA. The radiological prediction of inferior alveolar nerve injury during third

molar surgery. Br J Oral Maxillofac Surg 1990;28: 20–5.
9. Rud J. Third molar surgery: relationship of root to mandibular canal and injuries to inferior dental nerve. Tandlaegebladet 1983;87:619–31.
10. Valmaseda-Castellón E, Berini-Aytés L, Gay-Escoda C. Inferior alveolar nerve damage after lower third molar surgical extraction: a prospective study of 1117 surgical extractions. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2001;92:377–83.
11. Seward GR. Radiology in general dental practice. Br Dent J 1963;115:45–52.
12. Sedaghatfar M, August MA, Dodson TB. Panoramic radiographic findings as predictors of inferior alveolar nerve exposure following third molar extraction. J Oral Maxillofac Surg 2005;63:3–7.
13. Blaeser BF, August MA, Donoff RB, Kaban LB, Dodson TB. Panoramic radiographic risk factors for inferior alveolar nerve injury after third molar extraction. J Oral Maxillofac Surg 2003;61:417–21.
14. Nakagawa Y, Ishii H, Nomura Y, Watanabe NY, Hoshiba D, Kobayashi K *et al*. Third molar position: reliability of panoramic radiography. J Oral Maxillofac Surg 2007;65:1303–8.
15. Bundy MJ, Cavola CF, Dodson TB. Panoramic radiographic findings as predictors of mandibular nerve exposure following third molar extraction: digital versus conventional radiographic techniques. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2009;107:e36–40.
16. Rud J. Third molar surgery: perforation of the inferior dental nerve through the root. Tandlaegebladet 1983;87:659–67.
17. Mahasantipiya PM, Savage NW, Monsour PAJ, Wilson RJ. Narrowing of the inferior dental canal in relation to the lower third molars. Dentomaxillofac Radiol 2005;34:154–63.
18. Tantanapornkul W, Okouchi K, Bhakdinaronk A, Ohbayashi N, Kurabayashi T. Correlation of darkening of impacted mandibular third molar root on digital panoramic images with cone beam computed tomography findings. Dentomaxillofac Radiol 2009;38:11–16.
19. Tantanapornkul W, Okouchi K, Fujiwara Y, Yamashiro M, Maruoka Y, Ohbayashi N *et al*. A comparative study of cone-beam computed tomography and conventional panoramic radiography in assessing the topographic relationship between the mandibular canal and impacted third molars. Oral Surg Oral Med Oral Pathol Oral Radiol Endod 2007;103:253–9.
20. Friedland B, Donoff B, Dodson TB. The use of 3-dimensional reconstructions to evaluate the anatomic relationship of the mandibular canal and impacted mandibular third molars. J Oral Maxillofac Surg 2008;66:1678–85.
21. Flygare L, Öhman A. Preoperative imaging procedures for lower wisdom teeth removal. Clin Oral Investig 2008;12:291–302.
22. Öhman A, Kivijärvi K, Blombäck U, Flygare L. Pre-operative radiographic evaluation of lower third molars with computed tomography. Dentomaxillofac Radiol 2006;35:30–5.